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Special Issue on Silicon Carbide Devices and Technology

SINCE THE last TRANSACTIONS ON ELECTRON DEVICES Special Issue on SiC technology and devices, in March 1999, tentative steps have begun toward commercialization in several areas, e.g., power devices, UV sensors, and circuit modules. The commercialization trend should accelerate with further reductions in the basic material costs and with continued lowering of material defect densities, which should lead to improved device performance as well as enhancements in device yields. Since the last Special Issue impressive gains in the experimentally observed figures of merit for both power and high frequency devices have been realized, brought about by multiple changes, viz innovative and improved designs, better processing and lower defect densities. A particularly encouraging trend is the emerging interest in SiC power integrated circuits, including low-voltage and logic circuits. As expected, the thrust is toward fully integrated SiC power conditioning and RF transmitter modules. Certainly, the packaging of an entire SiC circuit in the same module has the advantage of the high temperature and high breakdown field properties of SiC.

A promising sign has been the increased diversity and progress made in power device switch development since the last Special Issue. At that time there were few SiC switches undergoing experimental study except for MOSFETs. Today MOSFETs still dominate, but SiC switches such as JFETs, MESFETs, gate turn-off thyristor structures, IGBTs and BJTs are also receiving attention.

The response to this Special Issue increased noticeably when compared to the previous one, indicating continued vigorous research activity in SiC devices and technology. Device papers heavily involved with processing, as well as material characterization, are strongly represented in the present issue (as they were in the 1999 issue). The continuation of this research activity should be viewed as a very positive influence. Indeed, the sought after improvements in SiC devices, in terms of performance and cost, will be severely hampered without continued progress and input from research in processing and materials.

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He joined the Department of Electrical and Computer Engineering, Rutgers University, NJ, in 1988, where he is currently the Director of SiCLAB and a Professor of electrical and computer engineering. His current research interests are focused on wide-bandgap semiconductor electronic and optoelectronic devices, circuits, and system applications with a major emphasis on energy-efficient power devices, power ICs, and various detectors, including single-photon counters. Together with his students and collaborators, he has published over 200 refereed journal and proceedings papers, six book chapters, and two books titled *Silicon Carbide: Materials, Processing, and Devices* (Taylor & Francis) and *Optical Filter Design and Analysis: A Signal Processing Approach* (Wiley, 1999), which was a top ten best seller at Amazon.com in 2000

under Corning Fiber Optics Series. He is the holder of one pending and six awarded U.S. patents, of which two have been licensed to industry.

Gerhard Pensl received the Ph.D. degree from the University of Erlangen, Nürnberg, Germany, in 1975.

In 1982 and 1984, he was a Visiting Scholar with Stanford University, Palo Alto, CA. In 1998 and 2005, he was a Guest Researcher with the Japan Atomic Energy Agency, Takasaki, Japan, for short periods. Since 1993, he has been the Academic Director of the Institute of Applied Physics, University of Erlangen. He was first involved with the study of nonlinear properties of ZnO. Then, he studied electron-phonon interaction and two-quantum absorption. In the early eighties, he started to investigate the deep levels of silicon and III-V compounds; these studies included pioneering work on deep-level transient spectroscopy and ion implantation. During the past 20 years, he has focused on the growth and characterization of the wide-bandgap semiconductor silicon carbide. He is the author of about 250 original contributions and reviewed articles on the electrical and optical properties of semiconductors. Further, he is a Coeditor of the *Proceedings of the Second International Conference on Insulating Films on Semiconductors*, the *Proceedings of the Seventh International Conference on Silicon Carbide, III-Nitrides and Related Materials*, and the *Proceedings of the Third European Conference on Silicon Carbide and Related Materials* and of the SiC compendia *Silicon Carbide—A Review of Fundamental Questions and Applications to Current Device Technologies* (1997) and *Silicon Carbide—Recent Major Advances* (2003).



Tsunenobu Kimoto (M'00) received the B.E. and M.E. degrees in electrical engineering and the Ph.D. degree, based on his work on SiC epitaxial growth, characterization, and high-voltage diodes, from Kyoto University, Kyoto, Japan, in 1986, 1988, and 1996, respectively.

He joined Sumitomo Electric Industries, Ltd., in April 1988, where he conducted research on amorphous-Si solar cells and semiconducting diamond materials. In 1990, he started his academic career as a Research Associate with Kyoto University. From September 1996 to August 1997, he was a Visiting Scientist with Linköping University, Linköping, Sweden, where he was involved in fast epitaxy of SiC and high-voltage Schottky diodes. He is currently a Professor with the Department of Electronic Science and Engineering, Kyoto University. His main research activity includes SiC epitaxial growth, optical and electrical characterization, ion implantation, MOS physics, and high-voltage devices. He has also been involved in nanoscale Si devices and novel materials for nonvolatile memory. He is the author of over 200 papers published in scientific journals and of more than 100 papers published in international conference

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Hiroyuki Matsunami received the B.E., M.E., and Ph.D. degrees from Kyoto University, Kyoto, Japan, in 1962, 1964, and 1970, respectively.

He has been with Kyoto University as a Research Associate since 1964, as an Associate Professor since 1971, and as a Professor since 1983. Since April 2003, he has been an Emeritus Professor of Kyoto University. He is currently the Director of Innovation Plaza Kyoto, Japan Science and Technology Agency. He was a Visiting Associate Professor with North Carolina State University, Raleigh, from 1976 to 1977. His professional work is on semiconductor science and engineering. He has also been working on semiconductor material synthesis, characterization, and device demonstration. He began his work on semiconductor SiC in 1968. He has worked on blue light-emitting diodes of SiC, heteroepitaxial growth of SiC on Si, and homoepitaxial growth of SiC on SiC substrates. He has greatly contributed to the progress in SiC devices by bringing high-quality epitaxial layers grown by the concept of step-controlled epitaxy, high-performance Schottky barrier diodes, and high-channel electron mobility in SiC MOSFETs. He is the author of more than 400 papers published in scientific journals and international conference proceedings. He is one of the three editors of *Silicon Carbide I and II* (Akademie, 1997) and *Silicon Carbide Recent Major Advances* (Springer, 2003).

Dr. Matsunami is a Fellow of Engineers and a member of the Institute of Electrical Engineers of Japan, the Japan Society of Applied Physics, and the Japanese Association of Crystal Growth. He is the recipient of the Outstanding Research Award from the Ministry of Education, the Japan Society of Applied Physics, and the Institute of Electronics, Information, and Communication.

Hajime Kosugi received the B.E. and M.E. degrees in electrical and electronic engineering from Kyoto University, Kyoto, Japan, in 2001 and 2003, respectively.

His research focused on the SiC oxidation process as well as the fabrication of SiC RESURF MOSFETs. After graduation, he joined Toyota Motor Corporation, where he has been working on power modules for hybrid electric vehicles.

James A. Cooper received the M.S.E.E. degree from Stanford University, Stanford, CA, in 1969 and the Ph.D. degree from Purdue University, West Lafayette, IN, 1973.

He is the Jai N. Gupta Professor of electrical and computer engineering at Purdue University. From 1973 to 1983, he was a Member of Technical Staff of Bell Laboratories, Murray Hill, NJ, where he was a Principal Designer of AT&T's first CMOS microprocessor and where he developed a time-of-flight technique to study high-field transport in silicon inversion layers. He joined the faculty of Purdue University in 1983, where he was the founding Director of the Purdue Optoelectronics Research Center. Since 1990, he has explored device technology in SiC. His group demonstrated the first monolithic integrated circuits in SiC (1993), the first DMOS power transistors (1996), and the first self-aligned short-channel DMOSFETs (2003). The group has also developed NVRAMs, CCDs, Schottky diodes, BJTs, IGBTs, SITs, and IMPATT diodes in SiC. He has coauthored over 240 technical papers and conference presentations and five book chapters. He is the holder of 13 U.S. patents. He has graduated 24 Ph.D. students and was a founding Codirector of the Birck Nanotechnology Center, Purdue University.

Prof. Cooper served as an Associate Editor for the IEEE TRANSACTIONS ON ELECTRON DEVICES from 1983 to 1986 and as a Coeditor of the 1999 and 2008 Special Issues of the IEEE TRANSACTIONS ON ELECTRON DEVICES on SiC technology. He currently serves on the editorial advisory board of *IEEE Proceedings*.



Maurice Weiner (F'92) received the Ph.D. degree in physics from New York University, New York, in 1971.

In 1961, he joined the U.S. Army Research Laboratory, Fort Monmouth, NJ, where he was engaged in the development of microwave ferrite and gaseous electronic devices. Later, as the Team Leader of the Solid State Pulsers Team, he led the development of optically activated semiconductors, thyristors, and other solid-state devices. In 1998, he joined United Silicon Carbide, Inc., New Brunswick, NJ, where he has helped develop research programs for various silicon carbide devices. He has served on numerous scientific panels and organized several workshops related to high-power semiconductor devices. He is the author of numerous publications and patents covering a variety of technical areas. He is also the author of *Electromagnetic Analysis Using Transmission Line Variables* (World Scientific, 2001).

Dr. Weiner was the Chairman of the 1994 IEEE Power Modulator Conference and served as a Coeditor of a Special Issue of the IEEE TRANSACTIONS ON ELECTRON DEVICES (December 1990) devoted to optically controlled semiconductor devices. He received the U.S. Army Research and Development Award in 1984, 1988, and 1992.